REFRIGERATION DEVICE AND OPERATING METHOD FOR SAME

The present invention relates to a refrigeration device with a thermally insulating housing enclosing an inner chamber and an evaporator arranged in the housing. Moisture from the inner chamber, which forms an ice layer over time, which in turn thermally insulates the evaporator from the inner chamber to be cooled, condenses on this evaporator during operation of the refrigeration device. This insulation impairs the efficiency of the refrigeration device, so that the ice layer must be thawed from time to time to maintain efficient operation of the refrigeration device.

For a user it is difficult to recognise the optimal defrosting point. Every defrosting procedure is associated with input of heat into the refrigeration device, which, when normal operation of the device is resumed, must be drawn off and thus likewise impairs the energy balance of the device. Excessively frequent defrosting is thus as ineffective as excessively infrequent defrosting.

It is therefore desirable to have a refrigeration device which enables, by means of assessing the ice thickness on the evaporator, an automatic decision to be made on whether a defrosting procedure is desirable or not.

For this purpose it would be appropriate to be able to measure the thickness of an ice layer directly on the evaporator and by means of this thickness automatically decide whether defrosting is required or not. Sensors, which enable direct measuring of the thickness of an ice layer on the evaporator, are costly however, and their service life is clearly shorter than that of the other components of conventional refrigeration devices, such that their use in a refrigeration device would clearly increase its susceptibility to repairs.

For this reason in most current no-frost refrigeration devices a time-controlled defrosting process is employed, that is, a monitoring circuit of the refrigeration device in each case triggers a defrosting procedure at fixed intervals. This technique is robust and cost-effective, however its disadvantage is that adaptation to different climate conditions, under which the refrigeration device is run, is not possible.

This means, a average "measured" time interval between two defrosting procedures can easily be too long if the device is operated in a warm environment, in which every time the door is opened a large quantity of moisture is introduced into the inner chamber and the ice layer on the evaporator grows rapidly as a result of this, whereas when the refrigeration device is operated in a cold environment with minimal moisture input an interval longer than the set time could improve the efficiency of the refrigeration device. Also, this technique cannot take into account the fact that the moisture input does not depend solely on the service life of the device, but also on the number of times the door is opened and on the type of cool goods stored in the device.

The object of the invention is to provide a refrigeration device, which enables reliable assessment of the quantity of ice accumulated on an evaporator with simple and robust means, and an operating mode for such a refrigeration device.

This task is solved by a refrigeration device having the characteristics of Claim 1 and an operating method having the characteristics of Claim 6.
The invention utilises the change in temperature distribution in the vicinity of the evaporator resulting

from the presence of an ice layer. If the evaporator is ice-free, this results in an extensively unhindered flow of heat in the vicinity of the evaporator, the temperature gradient is relatively flat, and the difference between the temperatures detected by the two sensors is minimal. If the heat flow is hampered by an ice layer, however, the result is a relatively steep temperature gradient in the ice layer, leading to greater differences between the temperatures detected by the two sensors, than when both sensors are ice-free.

One of the temperature sensors in particular can be placed directly on the surface of the evaporator and the other at a distance from the surface. This ensures that at least the first one will react very quickly to a change in temperature of the evaporator, which occurs whenever the evaporator begins to be supplied with coolant again after a standing phase.

Yet it is also conceivable to place both temperature sensors in each case in different though not remote distances from the surface of the evaporator.

Such an arrangement reacts only slightly sensitively to ice layer thicknesses insufficient for embedding one of the temperature sensors; however, as soon as the limit of the ice layer is between the sensors, the temperature difference detectable between them reacts very sensitively to a further increase in the layer thickness.

The invention is applicable to refrigeration devices with an evaporator arranged directly in the inner chamber or in thermal contact with the latter.
With such refrigeration devices automatic defrosting of the evaporator by means of an inbuilt heating device is not advised, because the heat given off by it is distributed in

the inner chamber of the refrigeration device and any cool goods contained therein are also warmed up.

The output signal delivered by the monitoring circuit can however be used in such a refrigerating device to control a display which advises a user of the necessity for defrosting.

A preferred application of the invention is a no-frost refrigeration device, that is, refrigeration devices, in which the evaporator is placed in a channel communicating with the inner chamber and in this channel can be warmed for defrosting, without the inner chamber necessarily having to be warmed also.

In such a refrigeration device one of the temperature sensors is preferably placed on the surface of the evaporator and the other is placed on an output of the channel terminating in the inner chamber.

Further characteristics and advantages of the invention will emerge from the following description of embodiments with reference to the attached figures, in which:

Figure 1 shows a schematic section through a refrigeration device according to a first embodiment of the invention;

Figure 2 shows the dependence of the temperature difference detected by the sensors on the thickness of the ice layer on the evaporator in the embodiment of Figure 1;

Figure 3 shows a schematic detail of a second embodiment of an inventive refrigeration device; and

Figure 4 shows the correlation between ice layer thickness and temperature difference according to the second embodiment.

Figure 1 shows a sketch of a no-frost refrigeration device according to a first embodiment of the invention. The refrigeration device conventionally comprises a thermally-insulating housing 1, in which an inner chamber 2 for receiving cool goods and an evaporator chamber 5 separated from the inner chamber 2 by a partition 3, is formed by openings 4 in the partition 3 communicating with the inner chamber 2. Arranged in the evaporator chamber 5 is a plate-like evaporator 7 supplied with coolant by a refrigerating machine 6 and, in close contact with the latter, a defrosting unit 8.

The evaporator chamber 5 and the openings 4 are designated jointly also as air duct.

A monitoring circuit 10 controls operation of the refrigerating machine 6 and a ventilator 11 arranged on the upper opening 4 by means of a measuring signal by a (not shown) temperature sensor in the inner chamber 2. Refrigerating machine 6 and ventilator 11 can in each case be run at the same time; it is preferred to switch the ventilator 11 on and off in each case with a certain delay relative to the refrigerating machine 6, so as to first give the evaporator 7 the opportunity to cool down before air is circulated when the refrigerating machine 6 is started up, and so as to continue utilising residual cold of the evaporator 7 after the refrigerating machine 6 is switched off.
A first temperature sensor 12 is attached directly to a surface of the evaporator 7, which is stroked by the air current circulating through the air duct when the ventilator 11 is running and on which as a result moisture precipitates

from this air current and over time forms an ice layer 13, shown as a lightly hatched surface.

A second temperature sensor 14 is arranged in the upper opening 4, from which air cooled in the evaporator chamber 5 flows back to the inner chamber 2.

To keep the temperature in the inner chamber 2 in a nominal range, the evaporator 7 is conventionally operated at intervals, that is, supplied by the refrigerating machine 6 with liquid coolant. The monitoring circuit 10 detects the difference between the temperatures measured by the sensors 12 and 14 in each case with a preset time delay from when the evaporator is started up or at a point in time when the change in speed of the temperature detected by one of the temperature sensors 12, 14 has fallen below a limit value and therefore can be assumed that the temperature distribution in the air duct is no longer all that far removed by stationary distribution. The difference between the temperatures detected by the temperature sensors 12, 14 at such a point in time is at the lowest when the thickness of the ice layer is zero, and it increases with the thickness of the ice layer. This is illustrated in the graphs of Figure 2, showing the temperature difference ΔT as a function of the layer thickness d. If this temperature difference ΔT exceeds a limit value ΔT_{max}, it is assumed that the ice layer 13 has exceeded a critical thickness d_{max}, requiring defrosting of the evaporator 7. If this is the case, the monitoring circuit 10 waits until the inner chamber 2 is sufficiently cooled down for the refrigerating machine 6 and the ventilator 11 to be switched off, and then closes a switch 9, via which the defrosting heating unit 8 is supplied with current.

The period, during which the switch 9 remains closed, is preset and considering the performance of the defrosting

heating unit 8 is selected such that the quantity of heat given off in this period must suffice to thaw the ice layer 13.

Figure 3 schematically illustrates an enlarged detail of a refrigeration device according to a second embodiment of the invention. It is distinguished from the embodiment of Figure 1 only by the placing of the temperature sensors 12', 14', so that the refrigeration device does not have to be illustrated and described in its entirety.

The two temperature sensors 12', 14' are held here on a carrier 15 made of a poor heat-conducting material, which is attached, e.g. adhered to a surface of the evaporator 7, on which an ice layer 13 can form.

Figure 4 shows the temperature difference ΔT detected under the same conditions as in the embodiment of Figure 1 between the sensors as a function of the thickness d of the ice layer. As long as the thickness of the ice layer is less than the distance d1 of the temperature sensor 12' from the surface of the evaporator 7, both temperature sensors are subjected to the air current in the evaporator chamber 5, and their temperature is determined substantially by that of the air current. Since the distancing of the second temperature sensor 14' from the evaporator 7 is greater than that of the first sensor 12', the second sensor is in any case slightly warmer than the first. As soon as the ice layer 13 begins, however, to grow out over the first sensor 12', it impairs the temperature balance between the sensors, and the temperature of the sensor 12' is determined as stronger than previously by the temperature of the evaporator 7, recognisable on a kink in the curve of Figure 4 by the thickness d1. The temperature difference ΔT therefore now begins to grow fast with the layer thickness d. The temperature difference, corresponding to the critical

layer thickness dmax, can take on another value $\Delta T_{max}'$ than in the embodiment of Figure 1. Since a large increase in the curve of Figure 4 can be realised in the vicinity of dmax, precise and reproducible detection of the critical layer thickness dmax is possible.